Effect of Root Temperature on the Concentration of Various Forms of Phosphorus in Cucumber and Figleaf Gourd Plants

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Abstract

An experiment was conducted with young plants of 2 ecotypes of cucumber (*Cucumis sativus L.*), i. e. the summer and the spring cultivar, and figleaf gourd (*Cucurbita ficifolia Bouché*) in order to know the effect of root temperature on the metabolism of phosphorus (P) in plants with contrasting tolerance to low root temperature. Concentrations of P in the various P fractions of leaves and roots were determined on plants grown at 12, 15, 18 and 23℃ root tempertures for 8 days. Lowering root temperature caused to decrease in the concentrations of total P in the leaves and roots of both cultivars of cucumber, but not of figleaf gourd. In cucumber, it was only the inorganic P that decreased significantly in response to low root temperature in both leaves and roots. P concentrations in the various organic P fractions were less affected in both plant parts of all 3 crops. Rather, organic P in the roots tended to increase towards lower root temperatures. Concentrations of lipid-P and PNA-P at lower root temperatures were significantly higher in figleaf gourd roots than in cucumber roots. The results and their implications are discussed.

Introduction

Reduction in root temperature retards plant growth and the utilization of P by the plants(3, 5, 14). Causal relationships between the decrease in P concentrations in plants and the suppression of growth have been a subject of study for decades from both theoretical and practical viewpoints. Effect of P addition to the rooting medium to improve growth at low root temperature has been studied by many investigators, but the results obtained are not consistent (10, 12, 19). Hori et al. (10) pointed out that the improved growth by P addition reported in literature was attributable to the low level of P in the soil used, and suggested that the low root temperature exerts its effect on plant growth primarily throught mechanisms independent of P nutrition in plants.

On the other hand, Chapin (4) found a negative correlation to exist between the soil temperature of the habitat of the plants and the rate at which they absorb P at low root temperature. As shown previously (17), low root temperature suppressed the absorption of P more greatly in cucumber than in figleaf gourd. Figleaf gourd is widely used as root-stocks of cucumber for winter crops, since it has higher tolerance to low root temperature (root-chilling tolerance) than cucumber (9, 15). Whether the degree of root-chilling tolerance of these plants is determined by the P nutrition of the plants is left to be elucidated.

P is present within the plant in the forms of inorganic and various organic compounds, and they play important roles in over-all plant metabolisms. Therefore, it seems worthwhile to know the effect of root temperature on the P metabolism in plants with contrasting root-chilling tolerance. The problem has been studied little to date.

The present paper presents the results on the effect of root temperature on the concentration of various P compounds in the leaves and roots of cucumber ecotypes, the summer and the spring cultivar, and figleaf gourd, the root-chilling tolerance of which increases in the order described (15).

Materials and Methods

Young plants of cucumber, the summer cultivar 'Suyô' and the spring one 'Kurume-ochiai H', and figleaf gourd were planted in a third strength Hoagland No. 1 solution in a growth room. Conditions of air temperature and light were the same as described previously (15). They were grown at 20℃ solution (=root) temperature for 2 days, and thereafter at 12, 15, 18, and 23℃ for 8 days. Afterwards, leaf blades and roots were sampled, freeze-dried and analyzed for various P compounds.

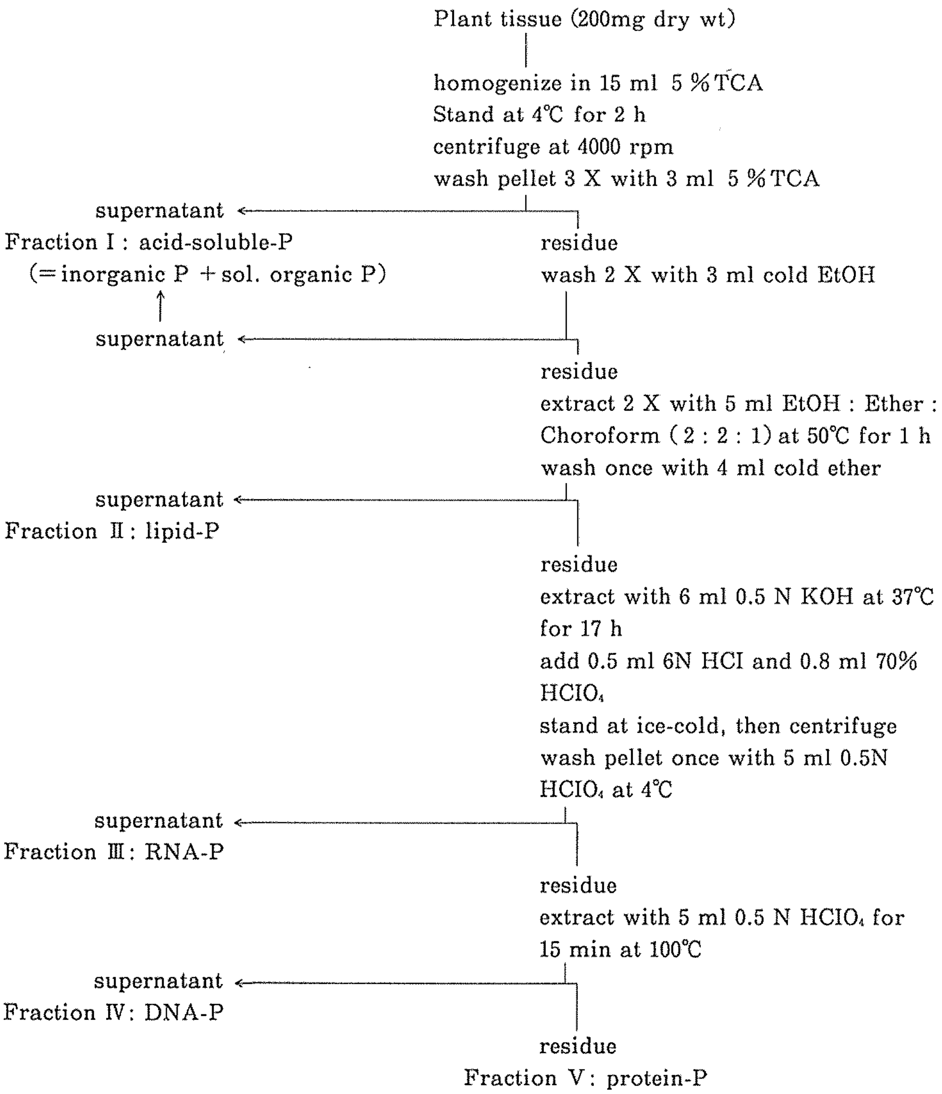

Fig. 1. Methods of P fractionation.

The method of P fractionation is a modification of that described by Hogue et al. (8) and summarized in Fig. 1. Inorganic P and total P of the various fractions were determined by the procedure of Bartlett (1). An aliquot of fraction I was used for the determination of inorganic P, and the rest was digested in HNO_3-$HClO_4$ to determine total acid soluble P, the difference (total acid soluble P − inorganic P) represented the acid soluble organic P. All the other fractions were acid-digested directly, and determined for P concentrations. Total P in the tissues was separately determined by the vanado-molybdophosphoric yellow color method.

Results

As shown in Fig. 2, concentrations of total P in the leaves of both cultivars of cucumber decreased almost linearly towards the lowest root temperature. Sharp decrease was observed between 18 and 15℃ in 'Suyô'. On the other hand, those in the roots decreased significantly only at 12℃. In contrast, in figleaf gourd, total P varied only slightly with changes in root temperature in both leaves and roots.

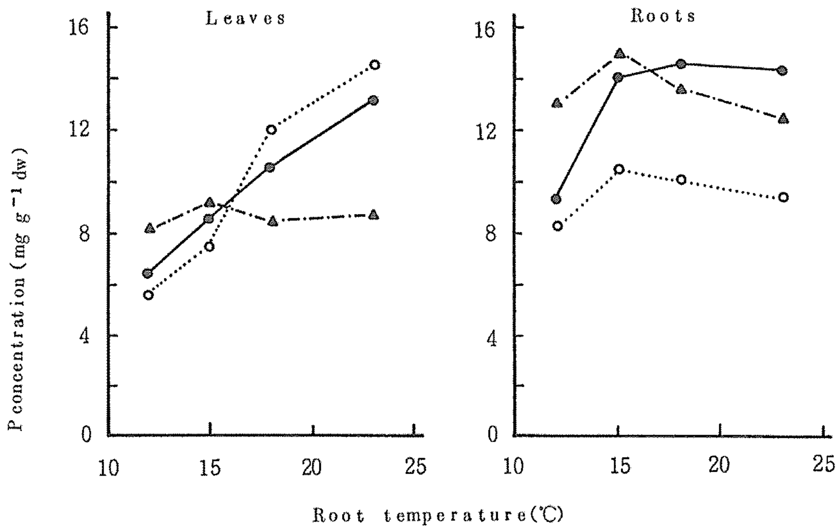

Fig. 2. Concentrations of total P in the leaves and roots of cucumber cv. 'Kurume-ochiai H' (●) and 'Suyô' (○) and figleaf gourd (▲) grown at different root temperatures.

Fig. 3 shows the concentrations of P in inorganic and various organic P fractions in the leaves. The major portion of the total P was found in the inorganic form in all 3 crops, irrespective of root temperature. It should be noted that the concentration of P varied approximately in parallel with those of total P. P concentrations in the various organic P fractions were found to be relatively constant over the entire range of root temperature, except that lipid-P in cucumber leaves decreased gradually as the root temperature was lowered. From these results it can be concluded that reduction in the amount of total P in leaves and roots of lower root temperatures is primarily ascribable to the reduction in the inorganic P.

P concentrations in the various P fractions of roots are shown in Fig. 4. In common with leaves, it was the inorganic form of P that decreased almost in parallel with total P. On the other hand, P concentrations in the organic P fractions generally tended to increae towards lower root temperatures, with several exceptions. However, the increase of lipid-concentrations was not great as compared with that found in the previous experiment (16). Concentrations of acid soluble organic P in figleaf gourd roots were lower than those in cucumber roots, regardless of root temperature.

A very interesting difference between cucumber and figleaf gourd roots was observed in RNA-P. The concentration was higher at 12-15℃ than at 18-23℃ in figleaf gourd roots, while in both cultivars of cucumber it turned to become lower at 12℃ than at 14℃. As a result, the concentraion at 12℃ was higher in the the former corp roots. Concentrations of DNA-P and protein-P were not affected by root temperature in all crops, ranging from 0.15 to 0.22, 0.07 to 0.10 in leaves and 0.28 to 0.35, 0.20 to 0.32 in roots, respectively.

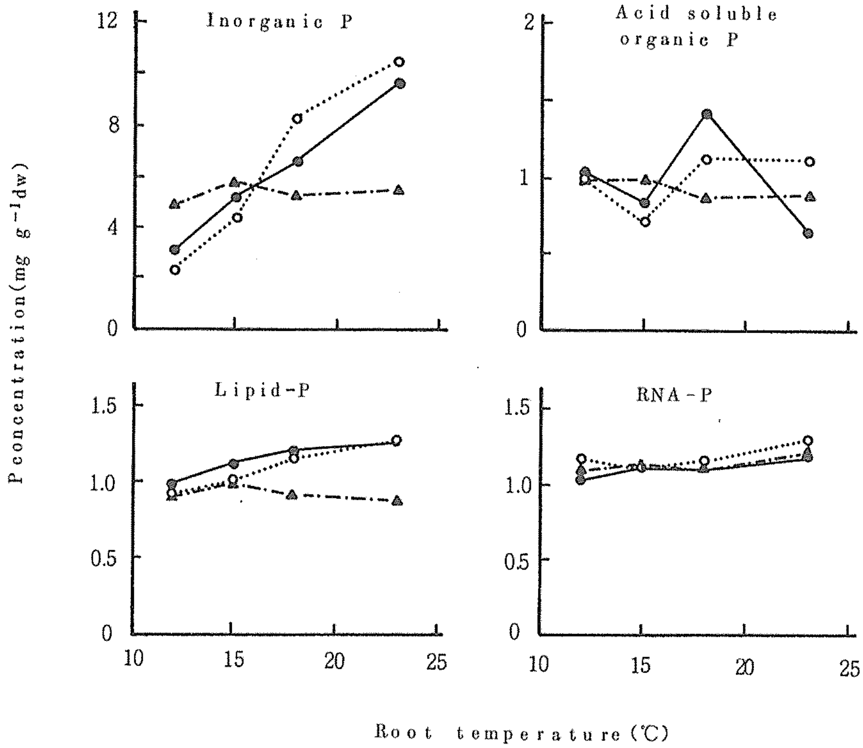

Fig. 3. P concentrations in various P compounds in the leaves of cucumber cv. 'Kurume-ochiai H' (●) and 'Suyô' (○) and figleaf gourd (▲) grown at different root temperatures.

Fig. 5 shows the percentage composition of P in various P fractions in the leaves and roots. As a rule, inorganic P constitued approximately 60 to 70% of the total P concentrations at 23℃ in both leaves and roots in all 3 corps. Evidently, reduction in root temperature caused predominantly to decrease the percentages of inorganic P in cucumber, in that 'Suyô' was more greatly affected than 'Kurume-ochiai H'. Figleaf gourd was little influenced by root temperature in this respect.

Discussion

Generally, when the absorption of P is reduced, the level of inorganic P decreases antecedently to the levels of P in various organic P fractions (8, 13, 21). In the present study the reduction of total P in cucumber plants at low root temperature was mainly due to that of inorganic P. This may indicat e that the change in the P composition (Fig. 5) is caused by inhibition of P uptake by low root tempe-

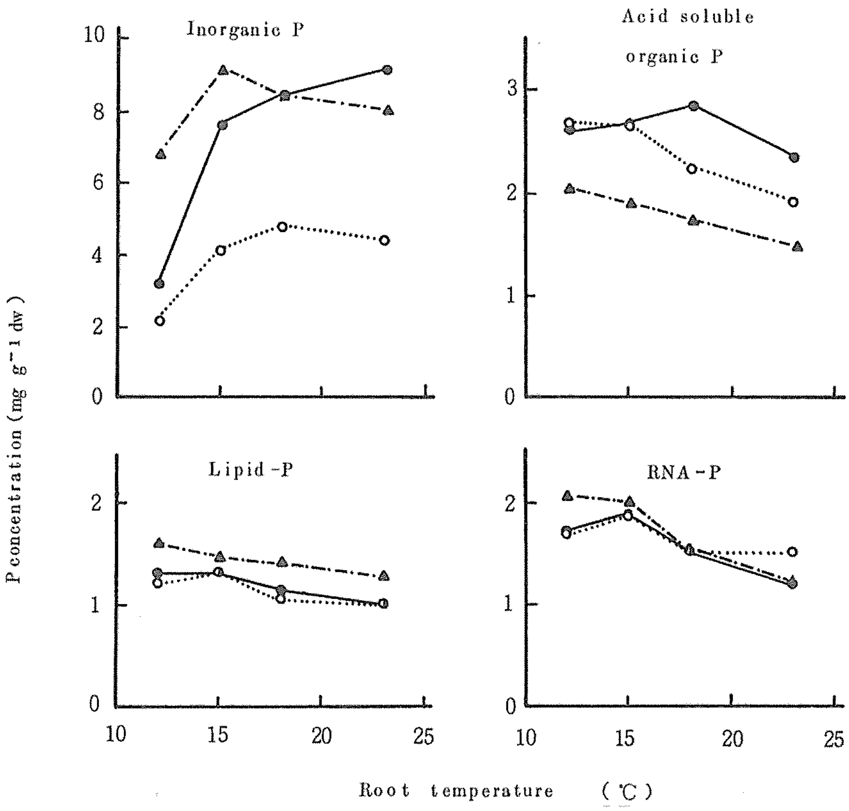

Fig. 4. P concentrations in various P compounds in the roots of cucumber cv. 'Kurume-ochiai H' (●) and 'Suyô' (○) and figleaf gourd (▲) grown at different root temperatures.

rature, and not by the distubance of P metabolism within plants. Decrease in lipid-P concentrations in cucumber leaves at lower root temperatures may also be resulted from P deficiency in plants (21).

A great part of inorganic P is segregated in the vacuole, and serves a storage function (2). However, inorganic P is also a substrate of most key biochemical reaction. The critical level of inorganic P for normal growth of plants has not yet been fully demonstrated. With tomato plants supplied with different levels of available P, Yasuda & Fujita (21) and Hogue et al.(8) found the level of inorganic P in the leaves to be about 0.4 ~ 0.5 mg g^{-1}dw when the growth rate was significantly reduced. According to Tadano & Tanaka (18), tomato is very sensitive to P deficiency in the soil. The level of inorganic P in cucumber leaves at 12℃, where plant growth was severely restricted, was about 5 times higher than the level described above (Fig. 2). It seems reasonable, therefore, to conclude that the lowered level of inorganic P in the leaves is not a cause of restricted growth of cucumber plants at low root temperature.

When plants are encountered a stress condition that would inhibit P uptake by the plants, decrease in the concentration of inorganic P does not necessarily precede that of organic P. Wilson & Huffaker (20) found in subterranean clover that the concentration of most phosphorylated compounds in plants under moisture stress decreased to less than half of that for control plants. The concentration of inorganic P was not affected. Also, Korovin (11) observed that lowering the root temperature caused to suppress P incorporation into organic compounds markedly, primarily into nucleotides, in both leaves

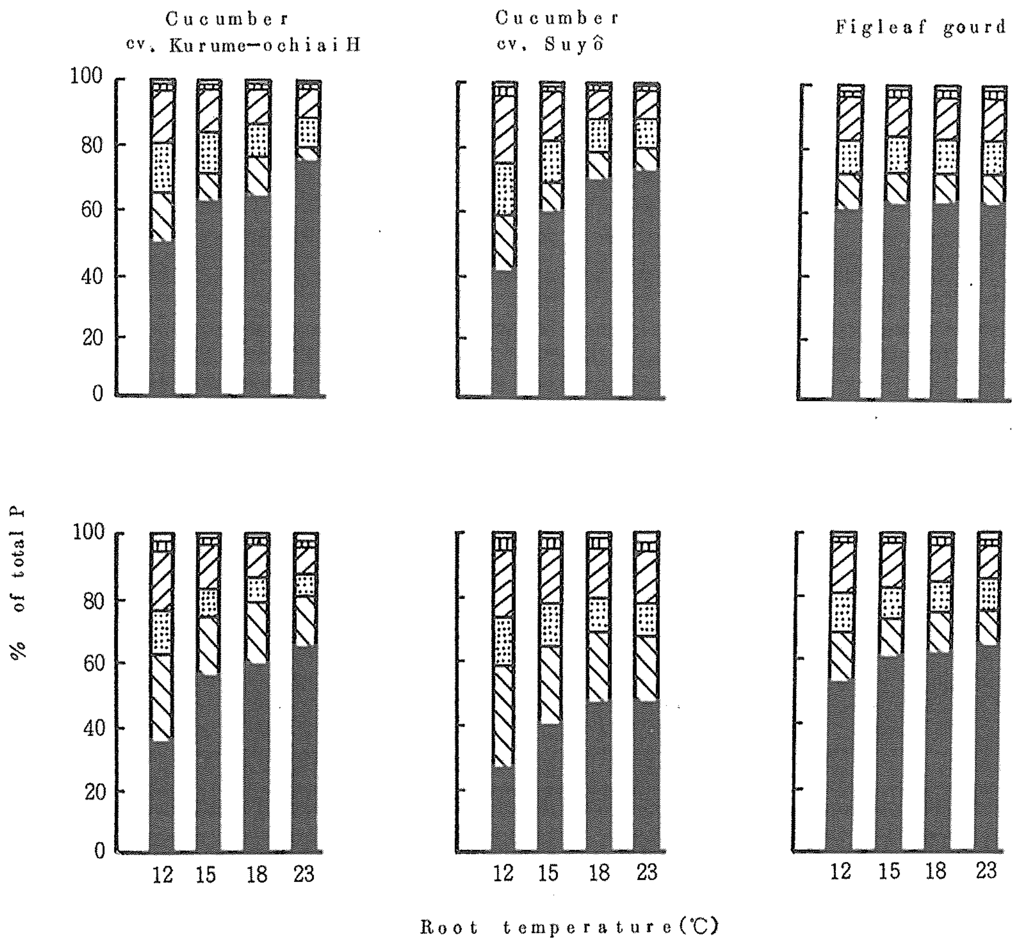

Fig. 5. Percentage composition of P in various P compounds in the leaves (upper) and roots (lower) as influenced by root temperature. ■ ; inorganic P, ⧅ ; acid soluble organic P, ⊡ ; lipid-P, ▨ ; RNA-P, ▥ ; DNA-P, □ ; protein-P.

and roots of wheat. As a result, inorganic P in percent of total P was greater at reduced root temperature. The results of the present study disagreed with the results of Korovin. Particularly in the roots, P concentraions in most organic P compounds augmented in response to low root temperature.

Parhaps, the difference in temperature response of RNA-P concentrations between cucumber and figleaf gourd roots, though not large, may have a significant physiological meaning in determining chilling tolerance of these plant roots. Gusta & Weiser (6) reported that during cold acclimation RNA (mainly rRNA) and soluble protein increased in the frost-resistant Korean boxwood. Furthermore, inhibitors of RNA synthesis was found to inhibit the development of frost hardiness in *Chlorella* cells (7). These results may suggest that the rate of RNA and protein synthesis at low temperature is an important factor determining cold hardiness of plants. Unpublished data in our laboratory showed that the incorporation of photosynthesized ^{14}C into soluble protein of roots was stimulated by low root temperature in figleaf gourd, but not in cucumber. Presumably, figleaf gourd roots respond to low temperature to stimulate RNA synthesis within the roots, which will result in increased synthesis of protein and eventually the stimulation of root growth *per se*, (15). More detailed study on RNA synthesis in the roots of cucumber and figleaf gourd as affected by root temperaure is now in progress.

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摘　　要

キュウリ品種とクロダネカボチャの葉及び根のりん化合物含有率に及ぼす根温の影響

橘　　昌　司

作物の低根温耐性と植物体のＰ栄養の関係について知るために，低根温耐性を異にするキュウリ２品種（'四葉'と'久留米落合H型'）及びクロダネカボチャを人工気象室で12，15，18，23℃の根温で８日間培養し，葉と根について種々のＰ化合物の分別定量を行った。

クロダネカボチャでは，葉，根ともに全Ｐ含有率は根温の影響をほとんど受けなかったが，キュウリでは特に葉の全Ｐ含有率が低根温によって低下した。分別定量の結果，葉，根ともに，無機態Ｐ含有率が他の分画の含有率Ｐに比べて高く，かつ全Ｐ含有率にほぼ並行して低下することが認められ，低根温によるＰ含有率の低下は主として無機態Ｐ含有率の低下によっていることが明らかとなった。

一方，有機態Ｐ分画では，キュウリの葉の脂質態Ｐを除いて，葉，根のいずれにおいても低根温によって含有率の低下する分画は３作ともになかった。むしろ，根においては有機態Ｐの各分画ともに低根温によってＰ含有率の増大する傾向がみられた。このなかで，ＲＮＡ態Ｐの含有率は，キュウリでは12℃で低下したのに対して，クロダネカボチャでは12℃まで増大を続け，12～15℃でキュウリより高い値となった。

これらの実験結果から，低根温によるＰ含有率の低下は直接的には生育抑制の原因ではないこと，及び低根温下での根のＲＮＡ合成能が作物の低根温耐性になんらかの関係を有することなどが示唆された。